PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 663364	**FOR FURTHER ACTION** See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/JP 02/12412	International filing date *(day/month/year)* 28.11.2002	Priority date *(day/month/year)* 28.11.2002
International Patent Classification (IPC) or both national classification and IPC H02P7/05		
Applicant MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD. et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 11 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the opinion
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand 24.11.2003	Date of completion of this report 22.02.2005
Name and mailing address of the international preliminary examining authority: European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized Officer Davis, A Telephone No. +31 70 340-2097

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17)):*

Description, Pages

2-26	as originally filed
1	received on 08.02.2005 with letter of 07.02.2005

Claims, Numbers

1-20	received on 08.02.2005 with letter of 07.02.2005

Drawings, Sheets

1/21-21/21	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).

   ☐ the language of publication of the international application (under Rule 48.3(b)).

   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.

   ☐ filed together with the international application in computer readable form.

   ☐ furnished subsequently to this Authority in written form.

   ☐ furnished subsequently to this Authority in computer readable form.

   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:

   ☐ the claims, Nos.:

   ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	2-11,13-20
	No:	Claims	1,12
Inventive step (IS)	Yes:	Claims	2-11,13-20
	No:	Claims	1,12
Industrial applicability (IA)	Yes:	Claims	1-20
	No:	Claims	

2. Citations and explanations

   see separate sheet

V Reasoned statement

1 Reference is made to the following documents:
D1: Fahimi et al: "Review of sensorless control methods in switched reluctance motor"
D2: EP-A-1 225 686

2 The claims, as far as they can be understood(see Article 6 PCT conciseness observation below), appear to lack either novelty or inventive step over the prior art in documents D1 and D2 above. The prior art of the search report and the originally filed description not cited here for this report would also appear to be significant in the inventive step evaluation of a claim which fulfilled the clarity (Article 6 PCT) and novelty requirements (Article 33(2) PCT).

3 The general idea of measuring phase current and DC link voltage in order to estimate rotor position in a control algorithm for an SRM is already known from both D1 and D2. It would therefore appear that the present application could only arrive at an allowable claim by referring to the exact details of the implementation and in particular where the claimed implementation features differ from those of the prior art. In particular it is understood that the skilled person appreciates the close correspondence between the inductance, flux-linkage and reluctance models of the switched reluctance machine which are often used as equivalent alternatives when considering control strategies. It is also understood that the skilled person is aware that measured or predicted induced voltages in unexcited phases is important when the windings are to be used in rotor position sensing.

3.1 It is well known that the rotor rotates in the opposite direction to the stator pole excitation and where each stator pole pair is excited the nearer rotor pole pair is pulled towards alignment using the well known alignment or reluctance torque. The skilled person is aware from the geometry of the SRM that the mutual inductance and therefore also reluctance varies between stator and rotor pole pairs as a function of rotor position. Thus the skilled person is also aware that in the normal operation o f an SRM there is a particular rotor position (i.e. a reference pole-pair-relative position) at which the active phase is switched off and the next phase is switched on and that this particular position corresponds to a particular flux-linkage between the active

stator pole pair and the nearest rotor pole pair being used to create torque (i.e. a reference pole-pair-relative flux linkage). Thus together with the D.C. link voltage and the phase current sensing which are known explicitly from D1 and D2 it would appear that the use of a reference pole-pair relative flux linkage is also implicitly known from D1 and D2.

Thus independent claim 1 would appear to lack novelty (Article 33(2) PCT) over D1 and D2.

4 It would appear that the applicant intends to direct the subject matter of the application to the combination of improvements, namely an improved method of SRM control together with sensorless position detection in an SRM. It particular it is understood that the manner in which the estimated rotor position is corrected is considered to be the contribution to the prior art. An amended claim in this direction would appear to remove the lack of unity objection raised in paragraph VIII below.

VIII Certain observations

1 Independent claims 1,2,3,4,6,7,8,9,12,13 and 14 lack clarity and conciseness (Article 6 PCT).

2 The claims refer to an aligned rotor position. This is understood to refer to the reference frame of the active stator pole pair but this is not clear from the wording of the claims (Article 6 PCT). Thus it is understood to refer to the fact that a rotor pole pair is aligned with a stator pole pair in a SRM.

3 The independent claims appear to lack unity (Rule 13 PCT) since claims which are directed towards the improvement of control of an SRM (i.e. claims 1, 12) do not appear to contribute towards the solution of claims directed toward the estimation of rotor position in an SRM (the other independent claims namely claims 2,3,4,6,7,8,9,13,14,).

4 Claims which refer to PWM interrupt timing would have to make clear that it is a microprocessor program cycle timing which is being interrupted (Article 6 PCT) which is not clear at present.

5 Some of the claims refer to a "stoke angle" which is unclear (Article 6 PCT)

DESCRIPTION

~~METHOD AND APPARATUS FOR ESTIMATING ROTOR POSITION OF SWITCHED RELUCTANCE MOTOR, AND METHOD AND APPARATUS FOR SENSORLESS CONTROL OF SWITCHED RELUCTANCE MOTOR~~

CONTROL METHOD OF SWITCHED RELUCTANCE MOTOR AND APPARATUS CONTROLLED THEREBY

Technical field

The present invention relates to the development of closed loop control techniques for switched reluctance motors (SRMs) without a shaft position sensor.

Background art

A switched reluctance motor (SRM) is energized phase by phase in sequence to generate reluctance torque and enable smooth motor rotation. A schematic diagram of a three phase switched reluctance motor is shown in Fig. 1. The number of strokes (N) in SRM per one mechanical revolution is dependent on the number of phases (M) and the number of rotor poles (P) and is given by,

$N = M*P$ (1).

Therefore, the stroke angle(S) in mechanical degrees is defined as,

$S = 360° / N$ (2).

When the number of poles is very large and the stroke angle is very small, the SRM is typically operated in open loop as a variable reluctance stepper motor and needs no knowledge of rotor position information during running condition. On the other hand, when the number of poles is small and the stroke angle is very large, the SRM is generally operated in closed loop during running

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Our Ref.: MA 7485-01WO JOE/ac

Applicant: MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.
Serial Number: PCT/JP02/12412

New claims

1. A control method of a switched reluctance motor comprising:

(a) sensing a d.c.-link voltage V_{dc} and a phase current I_{ph};

(b) calculating a flux-linkage λ_{ph} of an active phase from the sensed d.c.-link voltage V_{dc} and the sensed phase current I_{ph};

(c) comparing the calculated flux-linkage λ_{ph} with a reference flux-linkage λ_r, the reference flux-linkage λ_r related to a reference angle θ_r which lies between angles corresponding to aligned rotor position and non-aligned rotor position in the motor; and

(d) controlling a turn-off angle θ_{off} of each active phase and a turn-on angle θ_{on} of the next active phase, based on a timing at which the calculated flux-linkage λ_{ph} becomes greater than the reference flux-linkage λ_r.

2. A control method of a switched reluctance motor comprising:

(a) calculating an estimated rotor position θ_{est} by adding up an incremental rotor angle $\Delta\theta$ every predetermined control period;

(b) sensing a d.c.-link voltage V_{dc} and a phase current I_{ph};

(c) calculating a flux-linkage λ_{ph} of an active phase from the sensed d.c.-link voltage V_{dc} and the sensed phase current I_{ph};

(d) comparing the calculated flux-linkage λ_{ph} with a reference flux-linkage λ_r, the reference flux-linkage λ_r related to a reference angle θ_r which lies

between angles corresponding to aligned rotor position and non-aligned rotor position in the motor;

(e) when the calculated flux-linkage λ_{ph} becomes greater than the reference flux-linkage λ_r during the active conduction of a phase, performing once the following procedures including,

(a_1) determining estimated rotor position information θ_{cal} which is set at the reference angle θ_r related to the flux-linkage λ_r, or

(a_2) determining estimated rotor position information θ_{cal} from the flux-linkage λ_{ph} by using either one of a predetermined flux-linkage model or inductance model, or

(a_3) determining estimated rotor position information θ_{cal} by adding a correction angle Φ to the reference angle θ_r related to the flux-linkage λ_r; and

(b) calculating an absolute rotor position θ_{abs} by adding the estimated rotor position information θ_{cal} to a stoke angle of the motor, and

(c) determining and updating the incremental rotor angle $\Delta\theta$ by processing an error between the absolute rotor position θ_{abs} and the estimated rotor position θ_{est} through either one of a proportional-integral control and a proportional control; and

(f) controlling a turn-off angle θ_{off} of each active phase and a turn-on angle θ_{on} of the next active phase based on the estimated rotor position θ_{est}.

3. A control method of a switched reluctance motor comprising:

(a) sensing a d.c.-link voltage V_{dc} and a phase current I_{ph};

(b) calculating a flux-linkage λ_{ph} of an active phase from the sensed d.c.-link voltage V_{dc} and the sensed phase current I_{ph};

(c) comparing the calculated flux-linkage λ_{ph} with a reference flux-linkage λ_r, the reference flux-linkage λ_r related to a reference angle θ_r which lies between angles corresponding to aligned rotor position and non-aligned rotor position in the motor;

(d) when the calculated flux-linkage λ_{ph} becomes greater than the reference flux-linkage λ_r during the active conduction of a phase, performing once the following procedures including,

(a) determining estimated rotor position information θ_{cal} which is set at the reference angle θ_r related to the flux-linkage λ_r;

(b) calculating and updating an incremental rotor angle $\Delta\theta$ by using an elapsed time from the instant at which the estimated rotor position information θ_{cal} in the previous cycle is determined; and

(e) controlling a turn-off angle θ_{off} of each active phase and a turn-on angle θ_{on} of the next phase, based on the incremental rotor angle $\Delta\theta$, and the turn-off delay and turn-on delay relating to the reference angle θ_r.

4. A control method of a switched reluctance motor comprising:

(a) sensing a d.c.-link voltage V_{dc} and a phase current I_{ph};

(b) calculating a flux-linkage λ_{ph} of an active phase from the sensed d.c.-link voltage V_{dc} and the sensed phase current I_{ph};

(c) comparing the calculated flux-linkage λ_{ph} with a reference flux-linkage λ_r, the reference flux-linkage λ_r related to a reference angle θ_r which lies between angles corresponding to aligned rotor position and non-aligned rotor position in the motor;

(d) when the calculated flux-linkage λ_{ph} becomes greater than the reference flux-linkage λ_r during the active conduction of a phase, performing once the following procedures including,

(a_1) determining estimated rotor position information θ_{cal} from the flux-linkage λ_{ph} by using either one of a predetermined flux-linkage model and inductance model, or

(a_2) determining estimated rotor position information θ_{cal} by adding a correction angle Φ to the reference angle θ_r related to the flux-linkage λ_r; and

(b) calculating and updating an incremental rotor angle $\Delta\theta$ by using an elapsed time from the instant at which the estimated rotor position information θ_{cal} in the previous cycle is determined; and

(c) correcting a turn-on delay and a turn-off delay which are related to the reference angle θ_r based on the estimated rotor position information θ_{cal}; and

(e) controlling a turn-off angle θ_{off} of each active phase and a turn-on angle θ_{on} of the next phase, based on the incremental rotor angle $\Delta\theta$, and the corrected turn-off and turn-on delays.

5. The control method according to any one of claims 1 to 4, wherein the reference flux-linkage λ_r is expressed by a polynomial in the phase current I_{ph}.

6. A control method of a switched reluctance motor comprising:

(a) calculating an estimated rotor position θ_{est} by adding up an incremental rotor angle $\Delta\theta$ every predetermined control period;

(b) sensing a d.c.-link voltage V_{dc} and a phase current I_{ph};

(c) calculating a flux-linkage λ_{ph} of an active phase from the sensed d.c.-link voltage V_{dc} and the sensed phase current I_{ph};

(d) comparing the calculated flux-linkage λ_{ph} with a plurality of reference flux-linkages λ_{rn} (n=1,..,k), each of the reference flux-linkages λ_{rn} (n=1,..,k) related to each of reference angles θ_{rn} (n=1,..,k) which lie between angles corresponding to aligned rotor position and non-aligned rotor position in the motor;

(e) each time the calculated flux-linkage λ_{ph} becomes greater than each of the reference flux-linkages λ_{rn} during the active conduction of a phase, performing once the following procedures including,

(a₁) determining estimated rotor position information θ_{caln} (n=1,..,k) which is set at the reference angle θ_{rn} related to the flux-linkages λ_{rn}, or

(a₂) determining estimated rotor position information θ_{caln} (n=1,..,k) from the flux-linkage λ_{ph} by using either one of a predetermined flux-linkage model or inductance model, or

(a₃) determining estimated rotor position information θ_{caln} (n=1,..,k) by adding a correction angle Φ to the reference angle θ_{rn} related to the flux-linkages λ_{rn}; and

(b) calculating an absolute rotor position θ_{abs} by adding the estimated rotor position information θ_{caln} to a stoke angle of the motor, and

(c) determining and updating the incremental rotor angle $\Delta\theta$ by processing an error between the absolute rotor position θ_{abs} and the estimated rotor position θ_{est} through either one of a proportional-integral control and a proportional control; and

(f) controlling a turn-off angle θ_{off} of each active phase and a turn-on angle θ_{on} of the next active phase based on the estimated rotor position θ_{est}.

7. A control method of a switched reluctance motor comprising:

(a) sensing a d.c.-link voltage V_{dc} and a phase current I_{ph};

(b) calculating a flux-linkage λ_{ph} of an active phase from the sensed d.c.-link voltage V_{dc} and the sensed phase current I_{ph};

(c) comparing the calculated flux-linkage λ_{ph} with a plurality of reference flux-linkages λ_r (n=1,..,k), each of the reference flux-linkages λ_r (n=1,..,k) related to each of reference angles θ_r (n=1,..,k) which lie between angles corresponding to aligned rotor position and non-aligned rotor position in the motor;

(d) each time the calculated flux-linkage λ_{ph} becomes greater than each of the reference flux-linkages λ_m during the active conduction of a phase, performing once the following procedures including,

(a) determining estimated rotor position information θ_{caln} (n=1,..,k) which is set at the reference angle θ_m related to the flux-linkages λ_m;

(b) calculating and updating an incremental rotor angle $\Delta\theta_n$ (n=1,..,k) by using an elapsed time from the instant at which the estimated rotor position information θ_{caln} in the previous cycle is determined;

(c) when the calculated flux-linkage λ_{ph} becomes greater than the maximum reference flux-linkage λ_{rk}, averaging the incremental rotor angles $\Delta\theta_n$ (n=1,..,k) to determine and update an incremental rotor angle $\Delta\theta$; and

(e) controlling a turn-off angle θ_{off} of each active phase and a turn-on angle θ_{on} of the next phase, based on the incremental rotor angle $\Delta\theta$, and turn-off delay and turn-on delay related to the reference angle θ_m (n=1,..,k).

8. A control method of a switched reluctance motor comprising:

(a) sensing a d.c.-link voltage V_{dc} and a phase current I_{ph};

(b) calculating a flux-linkage λ_{ph} of an active phase from the sensed d.c.-link voltage V_{dc} and the sensed phase current I_{ph};

(c) comparing the calculated flux-linkage λ_{ph} with a plurality of reference flux-linkages λ_{rn} (n=1,..,k), each of the reference flux-linkages λ_{rn} related to each of reference angles θ_{rn} (n=1,..,k) which lie between angles corresponding to aligned rotor position and non-aligned rotor position in the motor;

(d). each time the calculated flux-linkage λ_{ph} becomes greater than each of the reference flux-linkages λ_{rn} during the active conduction of a phase, performing once the following procedures including,

(a) determining estimated rotor position information θ_{caln} (n=1,..,k) from the flux-linkage λ_{ph} by using either one of a predetermined flux-linkage model and inductance model,

(b) calculating and updating an incremental rotor angle $\Delta\theta$ by using an elapsed time from the instant at which the estimated rotor position information θ_{caln} in the previous cycle is determined,

(c) when the calculated flux-linkage λ_{ph} becomes greater than the maximum reference flux-linkage λ_{rk}, averaging the incremental rotor angles $\Delta\theta_n$ (n=1,..,k) to determine and update an incremental rotor angle $\Delta\theta$, and

(d) correcting a turn-on delay and turn-off delay which are related to the reference flux-linkages λ_{rn}, based on the estimated rotor position information θ_{caln}; and

(e) controlling a turn-off angle θ_{off} of each active phase and a turn-on angle θ_{on} of the next phase, based on the incremental rotor angle $\Delta\theta$, and the corrected turn-off and turn-on delays.

9. A control method of a switched reluctance motor comprising:

(a) sensing a d.c.-link voltage V_{dc} and a phase current I_{ph};

(b) calculating a flux-linkage λ_{ph} of an active phase from the sensed d.c.-link voltage V_{dc} and the sensed phase current I_{ph};

(c) comparing the calculated flux-linkage λ_{ph} with a plurality of reference flux-linkages λ_{rn} (n=1,..,k), each of the reference flux-linkage λ_{rn} (n=1,..,k)

related to each of reference angles θ_{rn} (n=1,..,k) which lie between angles corresponding to aligned rotor position and non-aligned rotor position in the motor;

(d) each time the calculated flux-linkage λ_{ph} becomes greater than each of the reference flux-linkages λ_{rn} during the active conduction of a phase, performing once the following procedures including,

(a) determining estimated rotor position information θ_{caln} (n=1,..,k) by adding a correction angle Φ to the reference angle θ_{rn} related to the reference flux-linkages λ_{rn},

(b) calculating an incremental rotor angle $\Delta\theta_n$ (n=1,..,k) by using an elapsed time from the instant at which the estimated rotor position information θ_{caln} in the previous cycle is determined, and

(c) when the calculated flux-linkage λ_{ph} becomes greater than the maximum reference flux-linkage λ_{rk}, averaging the incremental rotor angles $\Delta\theta_n$ (n=1,..,k) to determine and update an incremental rotor angle $\Delta\theta$;

(e) controlling a turn-off angle θ_{off} of each active phase and a turn-on angle θ_{on} of the next phase, based on the incremental rotor angle $\Delta\theta$ and a turn-off delay and a turn-on delay which are determined according to the reference angle θ_{rn}.

10. The control method according to any one of claims 6 to 9, wherein the reference flux-linkage λ_{rn} (n=1,..,k) is expressed by a polynomial in the phase current I_{ph}.

11. The control method according to claim 2, 4, 6 or 9, wherein the correction angle Φ is calculated based on a variation $\Delta\lambda_{ph}$ of the calculated flux-linkage λ_{ph} and the phase current I_{ph}.

12. A control method of a switched reluctance motor comprising:

(a) calculating an estimated rotor position θ_{est} by adding up an incremental rotor angle $\Delta\theta$ every predetermined control period;

(b) sensing a d.c.-link voltage V_{dc} and a phase current I_{ph};

(c) calculating an estimated current I_s from the sensed d.c.-link voltage V_{dc}, the sensed phase current I_{ph}, and a value completely or approximately equal to the minimum value of a motor inductance;

(d) comparing the sensed phase current I_{ph} with the estimated current I_s; and

(e) controlling a turn-off angle θ_{off} of each active phase and a turn-on angle θ_{on} of the next active phase, based on a timing when an error between the sensed phase current I_{ph} and the estimated current I_s becomes equal to or less than a predetermined value.

13. A control method of a switched reluctance motor comprising:

(a) calculating an estimated rotor position θ_{est} by adding up an incremental rotor angle $\Delta\theta$ every predetermined control period;

(b) sensing a d.c.-link voltage V_{dc} and a phase current I_{ph};

(c) calculating an estimated current I_s from the sensed d.c.-link voltage V_{dc}, the sensed phase current I_{ph}, and a value completely or approximately equal to the minimum value of a motor inductance;

(d) comparing the sensed phase current I_{ph} with the estimated current I_s;

(e) when an error between the sensed phase current I_{ph} and the estimated current I_s becomes equal to or less than a predetermined value, performing once the following procedures including,

(a) determining a rotor position θ_{app} which is related to the estimated current I_s in advance,

(b) calculating an absolute rotor position θ_{abs} by adding the rotor position θ_{app} to a stoke angle of the motor, and

(c) determining and updating the incremental rotor angle $\Delta\theta$ by processing an error between the absolute rotor position θ_{abs} and the estimated rotor position θ_{est} through either one of a proportional-integral control and a proportional control; and

(f) controlling a turn-off angle θ_{off} of each active phase and a turn-on angle θ_{on} of the next active phase, based on the estimated rotor position θ_{est}.

14. A control method of a switched reluctance motor comprising:

(a) sensing a d.c.-link voltage V_{dc} and a phase current I_{ph};

(b) calculating an estimated current I_s from the sensed d.c.-link voltage V_{dc}, the sensed phase current I_{ph}, and a value completely or approximately equal to the minimum value of the motor inductance;

(c) comparing the sensed phase current I_{ph} with the estimated current I_s;

(d) when an error between the sensed phase current I_{ph} and the estimated current I_s becomes equal to or less than a predetermined value, performing once the following procedures including,

(a) determining a rotor position θ_{app} which is related to the estimated current I_s in advance;

(b) calculating and updating an incremental rotor angle $\Delta\theta$ by using an elapsed time from the instant at which the rotor position θ_{app} in the previous cycle is determined; and

(e) controlling a turn-off angle θ_{off} of each active phase and a turn-on angle θ_{on} of the next active phase, based on the incremental rotor angle $\Delta\theta$, and a turn-off delay and a turn-on delay which are related to the rotor position θ_{app}.

15. The control method according to any one of claims 2 to 4, 6 to 9, 13 and 14, further comprising correcting the turn-off angle θ_{off} of each active phase and the turn-on angle θ_{on} of the next active phase, based on a motor speed ω calculated from the incremental rotor angle $\Delta\theta$, and a torque command calculated based on an error between the motor speed ω and a speed command provided externally.

16. The control method according to any one of claims 1 to 4, 6 to 9, and 12 to 14, further comprising detecting a peak of the phase current I_{ph} and a rate of decrease in the phase current I_{ph}, and correcting the turn-on angle θ_{on} of the next active phase so that the detected peak and rate of decrease are predetermined values, respectively.

17. The control method according to any one of claims 1 to 4, 6 to 9, and 12 to 14, further comprising detecting a phase difference between a peak of the phase current I_{ph} and the calculated flux linkage λ_{ph}, and correcting the turn-on

angle θ_{on} of the next active phase so that the detected phase difference is a pre-determined value.

18. An apparatus which is controlled in the method according to any one of claims 1 to 4, 6 to 9, 12 to 14.

19. An apparatus comprising a compressor which is controlled in the method according to any one of claims 1 to 4, 6 to 9, 12 to 14.

20. The apparatus according to claim 19 which is an air conditioner.